RADIATION BIOLOGY & PROTECTION

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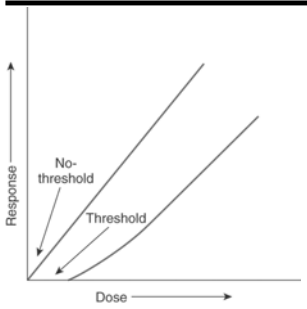
Radiobiology

The response of living systems to ionizing radiation

Dose-Response Curve



LINEAR RESPONSE TO RADIATION –

ASSUMES NO PHOTON IS SAFE

A. DIAGNOSTIC X-RAY - No Threshold –

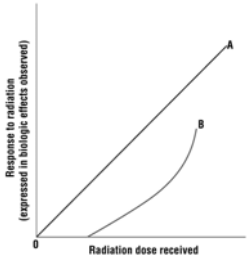
LOW DOSE – OVER LONG EXPOSURE

B. Early Radiology Exposure

Threshold amount needed to see affect

SOMATIC & GENETIC

STOCHASTIC VS NON STOCHASTIC



- ***A =***
  "CHANCE"EFFECTS

GENETIC Damage,
LEUKEMIA, CANCER
DIAGNOSTIC RADIOLOGY

B - Determined Dose

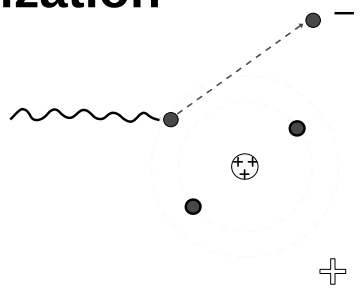
SKIN ERYTHEMA, CATARACTS, STERILITY

RAD -MALIGNANCIES

Ionization

The process of converting electrically neutral atoms into ions

Ionization



Ionizing Radiation

Electromagnetic
X-rays, gamma rays

Particulate
Alpha particles, electrons

Attenuation

Reduction of x-ray beam intensity (that reaches film) by interaction with matter

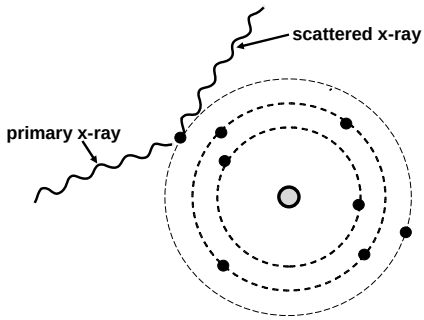
1. **Coherent scattering**
2. **Compton scattering**
3. **Photoelectric absorption**

9% of x-rays not attenuated

Coherent Scattering

Low-energy x-ray interacts with outer-shell electron and causes it to vibrate briefly. Scattered x-ray of same energy as primary x-ray is then emitted, going in a different direction than primary x-ray. Electron not ejected from atom. (No ionization).

Coherent Scattering



Compton Scattering

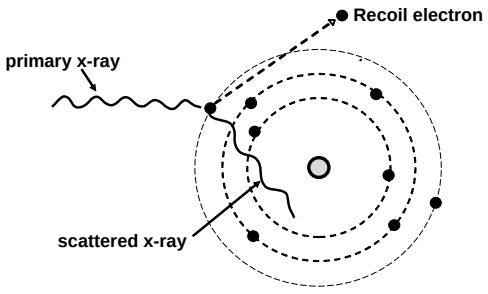
Outer shell electron ejected (Ionization)

Scatter radiation results

Occurs 62% of the time

30% of scatter exits head

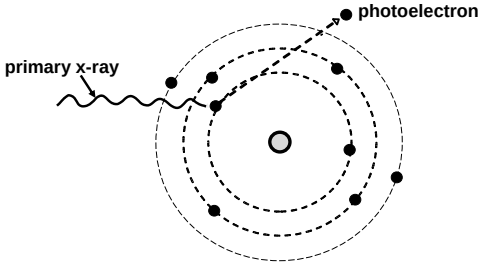
Compton Scattering



Photoelectric Absorption

- **Inner-shell electron ejected (Ionization)**
- **Low-energy characteristic x-rays produced**
- **Complete absorption**
- **Occurs 30% of the time**

Photoelectric Absorption



Basic Cell Structure

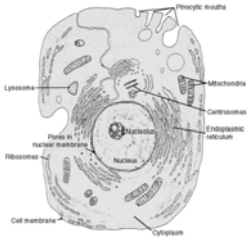
Two parts:

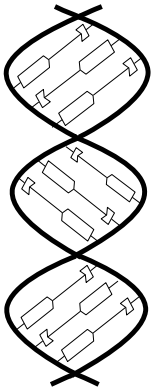
1. Nucleus
2. Cytoplasm

Nucleus contains chromosomes – genetic info (DNA)

DNA is at risk when a cell is exposed to ionizing radiation

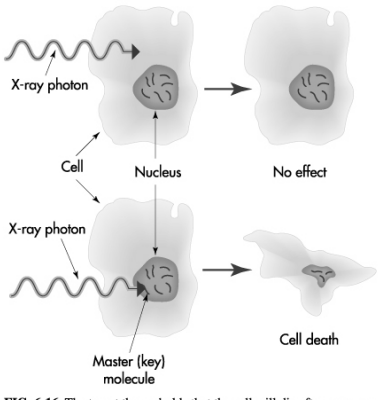
Cytoplasm – 80% water

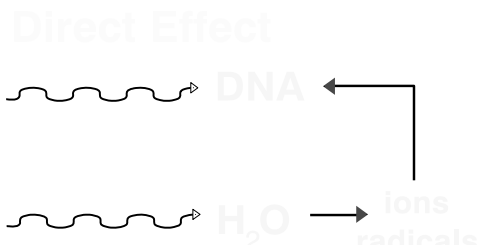




DNA

Critical Molecule (Target)





Radical

Atom or molecule that has an unpaired electron in the valence shell, making it highly reactive

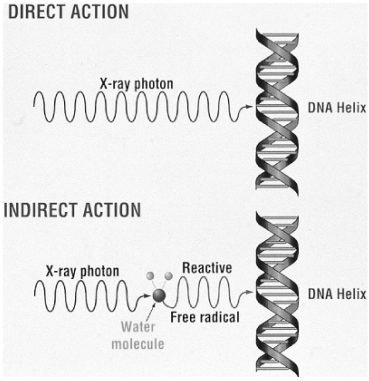
Cellular Absorption
Direct vs. Indirect Hit

Direct Hit Theory:

- When radiation interacts with DNA.
- Break in the bases or phosphate bonds
- Can injure or kill the cell

Indirect Hit Theory:

- Occurs when water molecules are ionized
- Produces chemical changes – injury or cell death
- Vast majority of cellular damage is from indirect hit.



Biologic Effects

Mutations

Cell death

Sublethal injury

Cellular Repair

1. **Damage to biologic molecules (single-strand break of DNA)**
2. **Removal of damaged section by cell enzymes**
3. **Placement of new material by other cell enzymes**

Radiosensitivity of Cells

- **Bergonie & Tribondeau (1906) – method of classifying a cell's response to radiation according to sensitivity.**
- **Cells are most sensitive during active division (primitive in structure & function).**

The Law of Bergonie & Tribondeaux

- Cells that are most sensitive to radiation
- Young – immature cells
- Stem Cells
- Highly dividing (mitotic) cells
- Highly metabolic

Radiosensitive Cells

Many mitoses

Undifferentiated

Germ cells, skin, mucosa, erythroblasts

Radioresistant Cells

Few mitoses

Well differentiated

Nerve, muscle, bone

Radiation Effects Influenced by:

Total dose
Dose rate
Total area covered
Type of tissue
Age

Whole-body Radiation

vs.

Specific-area Radiation

Somatic Cell Damage (affects individual)

vs.

Genetic Cell Damage (affects offspring)

Total Body Response to Radiation

- *Acute Radiation Syndrome* – full body exposure given in a few minutes.
- 3 stages of response:
  - *1. Prodromal Stage: NVD stage (nausea, vomiting, diarrhea)*
  - *2. Latent Period: Feels well while undergoing biological changes*
  - *3. Manifest Stage: Full effects felt, leads to recovery or death*

3 Acute Radiation Syndromes Early Effects

- **Bone marrow syndrome:** results in infection, hemorrhage & anemia
- **Gastrointestinal syndrome**: results in diarrhea, nausea & vomiting, fever
- **Central nervous syndrome:** results in convulsions, coma, & eventual death from increased intracranial pressure.

  CNS least sensitive in ADULTS –

  MOST sensitive in the FETUS

Late Effects of Radiation

- Somatic Effects: develop in the individual who is exposed

  Most common: Cataract formation & Carcinogenesis
- Genetic Effects: develop in future generations as a result of damage to germ cells.

DOSIMETRY

TYPES OF RADIATON (ALL CAUSE *IONIZATION)*

- **PARTICULATE**
- **ALPHA**
- **BETA**
- **FAST NEUTRONS**
- **Unit of mesaure is the curie (Ci) or becquerel (Bq)**
- **Very low energy =**
- **More destructive**

- **ELECTROMAGNETIC**
- **XRAY**
- **GAMMA**
- **(damaged caused by indirect action = free radicals – can be repaired)**

QUALITY FACTOR

Qualifies what the damage is from different types of radiation

- **Example: QF for X-ray is 1**
- **QF for alpha is 20**

- **Alpha is 20 x more damaging to tissue**

Units of Radiation Measurement

- To *quantify* the amount of radiation
- a patient
- or worker receives

Units of Radiation Measurement

Roentgen (R)	**Coulombs per kilogram**
rad	**Gray**
rem	**Sievert**

ROENTGEN (R)

- SI unit = C/KG
- THE QUANTITY OF X-RADIATION
- ONLY EXPOSURE IN AIR
- OUTPUT OF XRAY TUBE
- DOES NOT INDICATE ACTUAL PATIENT EXPOSURE OR ABSORBTION

RADIATION ABSORBED DOSE (RAD) SI = GRAY (Gy)

- MEASURES THE AMOUNT OF ENERGY ABSORBED IN ANY MEDIUM. (the patient)
- 1 Gy = 100 rads
- 1/100 Gy = 1 rad

Radiation Equivalent Man

- DOSE EQUIVALENT – Used for employee
- Traditional Unit = REM
- SI Unit = Sievert (Sv)
- 1 Sv = 100 rem

RADIATION EQUIVALENT MAN (REMS) SI UNITS = SEIVERT

- Not all types of radiation produce the same responses in living tissue
- The unit of dose equivalence, expressed as the product of the absorbed dose in rad (or gray) and quality factor.
- RAD x QF = REM
- used for occupational exposures
- *can be used when for dose of patient*

Rad VS. Rem

- 1 RAD X QF = 1 REM
- 1 GRAY X QF = 1 SIEVERT
- QF FOR X-RAYS = 1
- So…… Rads = Rems

R = 1 rad = 1 rem 1

1 Gray = 1 Sievert

1000 mrem = 1 rem

Why did the bunny die??

BUNNY A

- Received 200 rads

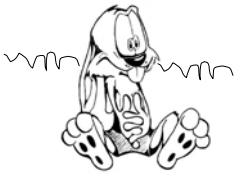
BUNNY B

- Received 200 rads

Why did the bunny die??

BUNNY A

200 rads x 1 for X-RAY = 200 REMs



BUNNY B

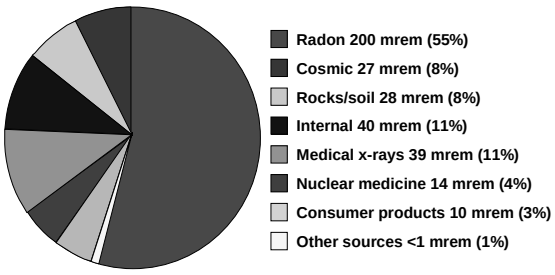
200 rads x 20 for alpha = 4000 REMs

Background Radiation

360 mrem/year
(3.6 mSv/year)

Background Radiation

360 mrem (3.6 mSv)/year



Background Radiation (Natural)

External (16%)
- Cosmic
- Terrestrial

Internal (Food - 11%)

Radon (55%)

Background Radiation (Man-made)

Medical (11%)
- (Dental - 0.1%)

Nuclear Medicine (4%)

Consumer Products (3%)

Surface Exposure

Periapical/BW:	100 mrem (F-speed) 250 mrem (D-speed)
Panoramic:	500 mrem
AFM:	2 rem (F-speed)
Lateral Ceph:	150 mrem
Chest Film:	20 mrem

1 mrem = .001 rem or 1000 mrem = 1 rem

Effective dose

- Effective dose is used in radiation protection, to compare the stochastic risk of a non-uniform exposure to ionizing radiation.
- It is not intended as a measure for acute or threshold effects of radiation exposure such as erythema, radiation sickness or death.

Effective Dose Equivalent

AFM (round, F)	6.8 mrem
AFM (rect., F)	2.7 mrem
Panoramic	0.7 mrem
Ceph	22.0 mrem
Chest	8.0 mrem

1 mrem = 10 µSv

Equivalent Background Exposure

FMS (round, F)	5 days bkgr
FMS (rect., F)	2 days bkgr
Panoramic (rare)	10 hours bkgr

MPD

Maximum Permissible Dose

Radiation Workers (Over 18)

50 mSv (5 rem) NCRP

General Public

5 mSv (0.5 rem) NCRP

1 mSv (0.1 rem) (Ohio)

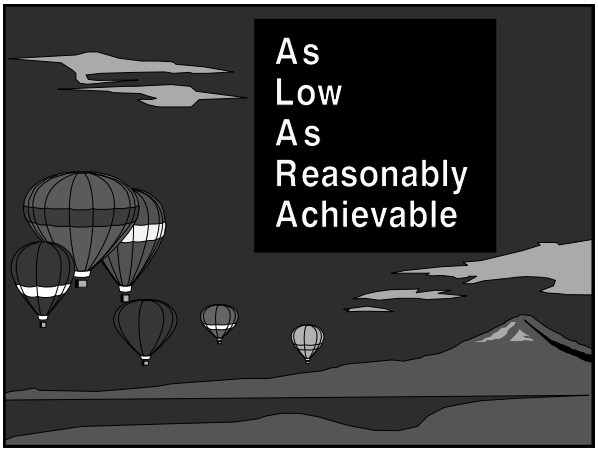
Pregnancy and Radiation

Since their cells are reproducing more often, developing embryos, fetuses, and children are typically more sensitive to radiation than adults.

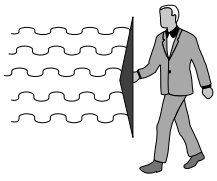
When the abdomen of a pregnant woman is exposed to radiation, a fraction of that exposure is also received by the embryo or fetus.

Fetus Exposure

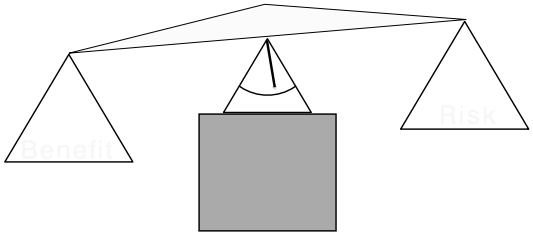
- **Radiation exposure is most harmful during the first trimester of pregnancy**
- **Embryo-Fetus Exposure limit**
  - **0.05 rem or 0.5 mSv PER MONTH**
  - **0.5 rem or 5 mSv total gestaion**



Radiation Protection



Risk vs. Benefit



Professional judgement

Selection criteria

Equipment Reliability

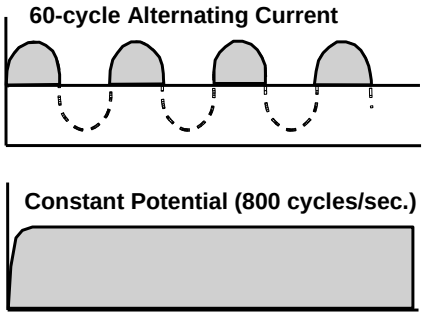
Leakage Radiation
Timer Accuracy
X-ray Production

Cardinal Principles of Protection

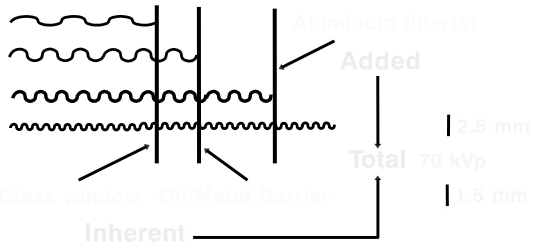
- **Triad of Radiation Safety**

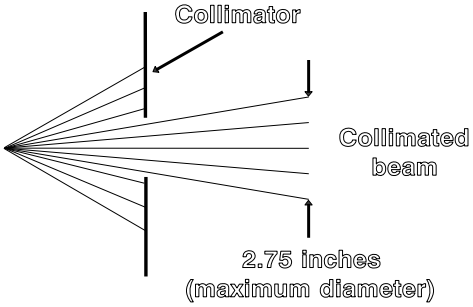
  1. **Time**
  2. **Distance**
  3. **Shielding**

***Apply to the patient & Technologist**

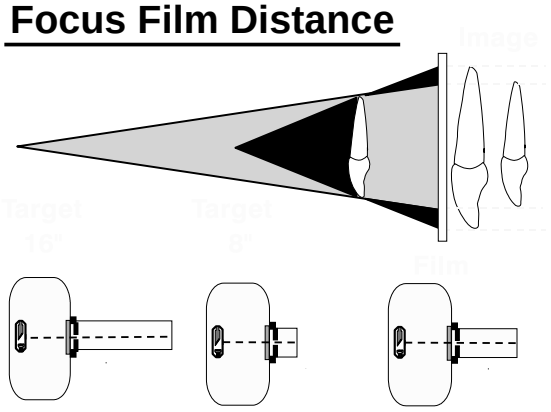


Total Filtration





Focus Film Distance



Intraoral Film Speed

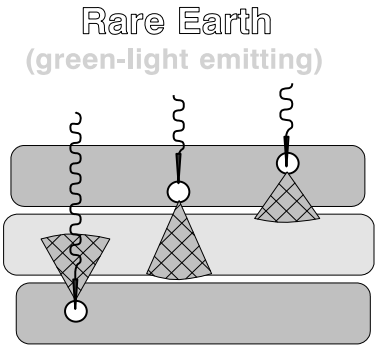
D-speed (Ultraspeed)

F-speed (Insight)

- **Larger silver halide crystals**
- **60 % less radiation than D**

Screen Speed

Fast	**less exposure** **less detail**
Medium	**compromise between speed and detail**
Slow (Detail)	**more detail** **more exposure**



Lead Apron

Psychology

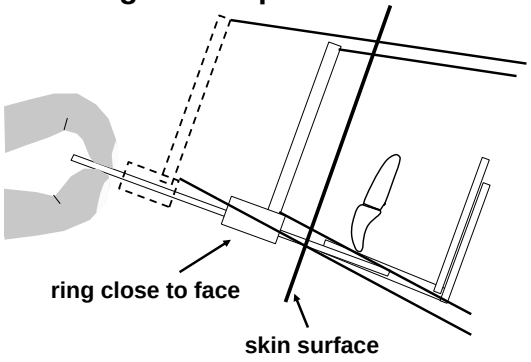
Protection

Lead Apron/
Thyroid Collar

Technique

Taking films - Proper film placement and exposure

Paralleling Technique



Processing

Correct time, temperature

Proper safelighting

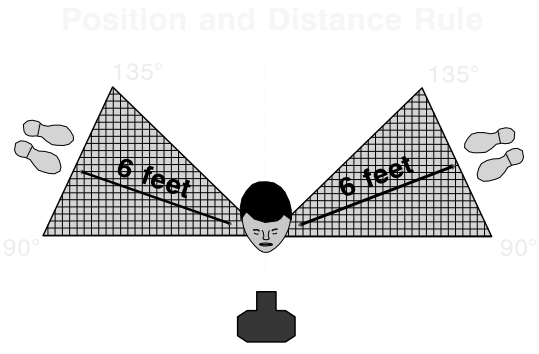
Light-tight darkroom

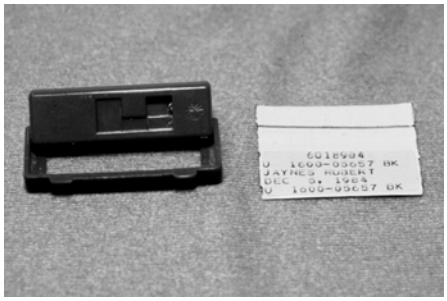
X-ray Protection for the Operator

Do not hold film for patient

Utilize barriers if available; drywall adequate

Follow position and distance rule





Required to wear film badge if you expect to exceed MPD during calendar quarter (1.25 rem)

Biologic effects of radiation

- **Dental radiographs during pregnancy**
  - **Radiation dose to fetus extremely low**
  - ***Needed* radiographs can be taken during pregnancy with usual precautions**
  - **Some dentists prefer to postpone until after delivery for peace of mind**
    - **However, untreated dental infections can harm fetus**